# *TRISO Fuels Status Report (ORNL/GA)*

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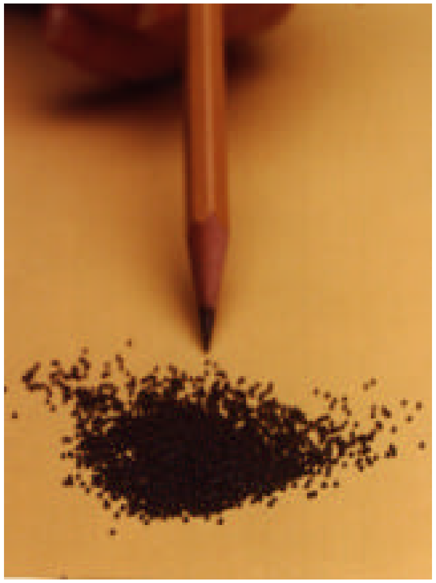
AAA Technical Quarterly Review
July 9, 2002



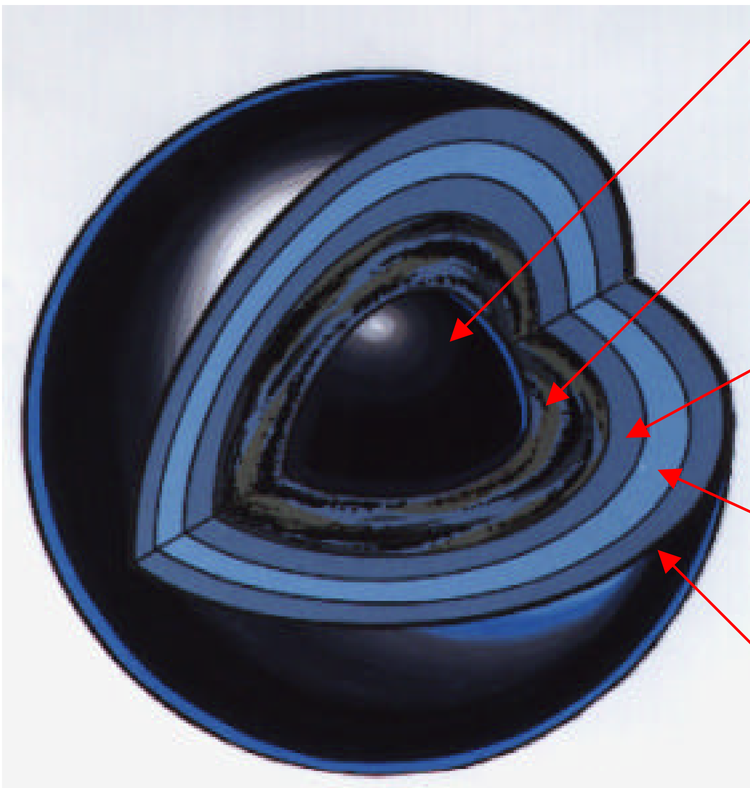
AAA Advanced Accelerator Applications

# *TRISO Fuels are Designed for High Burnup in Gas-Cooled Reactors*



**TRISO Coated Particles** ⟶ **Compacts** ⟶ **Fuel Assembly**

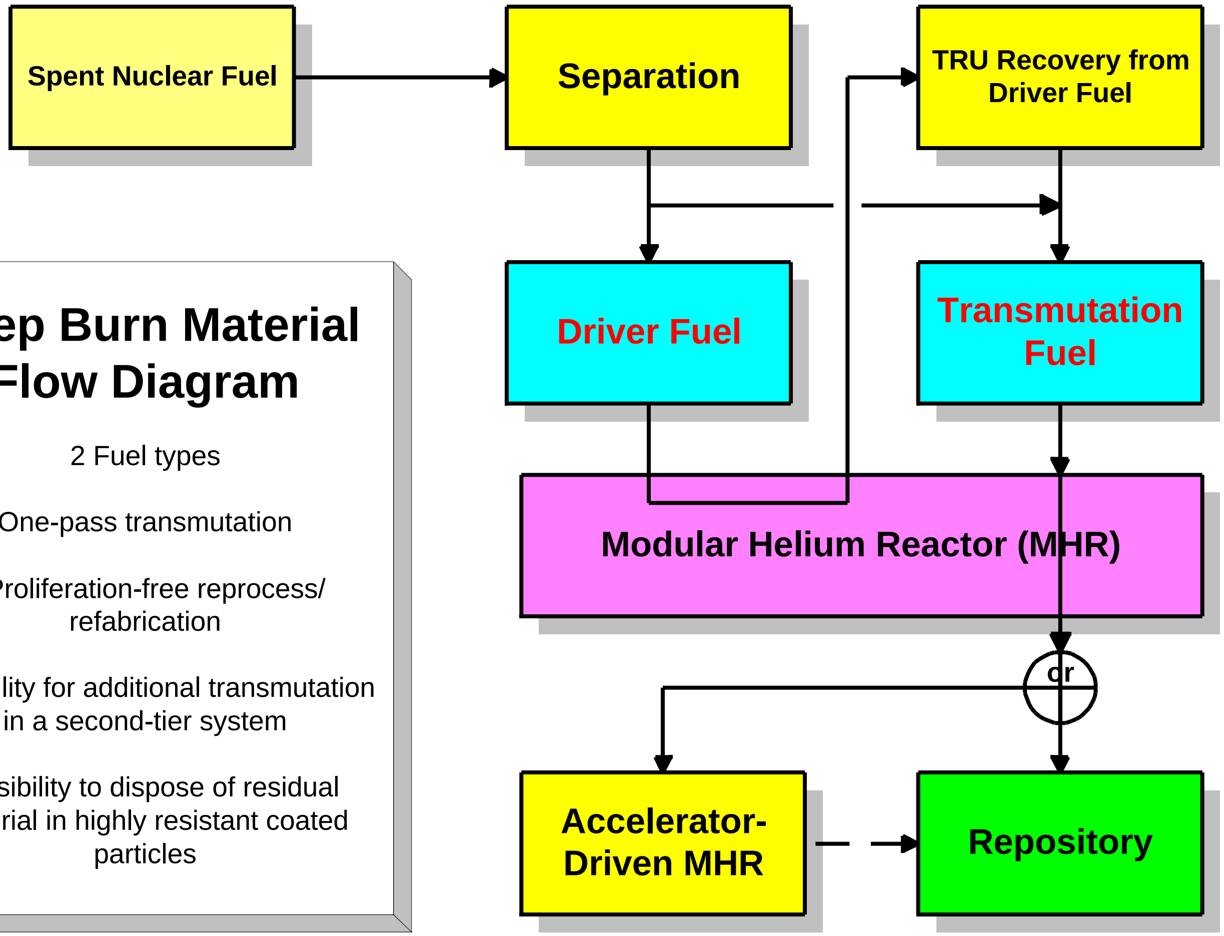
# *TRISO Particles Retain FP's at High Burnup/Temperature*



- Fuel Kernel
  - Provide fission energy/destroy Pu/MA
  - Retain fission products
- Buffer layer (porous carbon layer)
  - Attenuate fission recoils
  - Void volume for fission gases
- Inner Pyrocarbon (IPyC)
  - Provide support for SiC during manuf. and irrad.
  - Prevent Cl- attack of kernel during SiC deposition
  - Retain gaseous fission products
- Silicon Carbide (SiC)
  - Primary load bearing member
  - Retain gaseous and metal fission products
- Outer Pyrocarbon (OPyC)
  - Protects SiC from surroundings
  - Hold SiC in compression

**Driver Fuel: Pu/Np oxide**
**Transmutation Fuel: Pu/Np/Am/Cm oxide**

# Deep Burn Transmutation Minimizes Number of Fuel Treatment Cycles




## Deep Burn Material Flow Diagram

2 Fuel types

One-pass transmutation

1 Proliferation-free reprocess/ refabrication

Possibility for additional transmutation in a second-tier system

Possibility to dispose of residual material in highly resistant coated particles

# *FY02 Activities Support First Steps in Proof-of-Principle*

**Major FY02 Accomplishments/Milestones:**

**Non-Radioactive Surrogate TRISO Fabrication**

**Depleted Uranium TRISO Fabrication**

**Minor Actinide Kernel Fabrication**

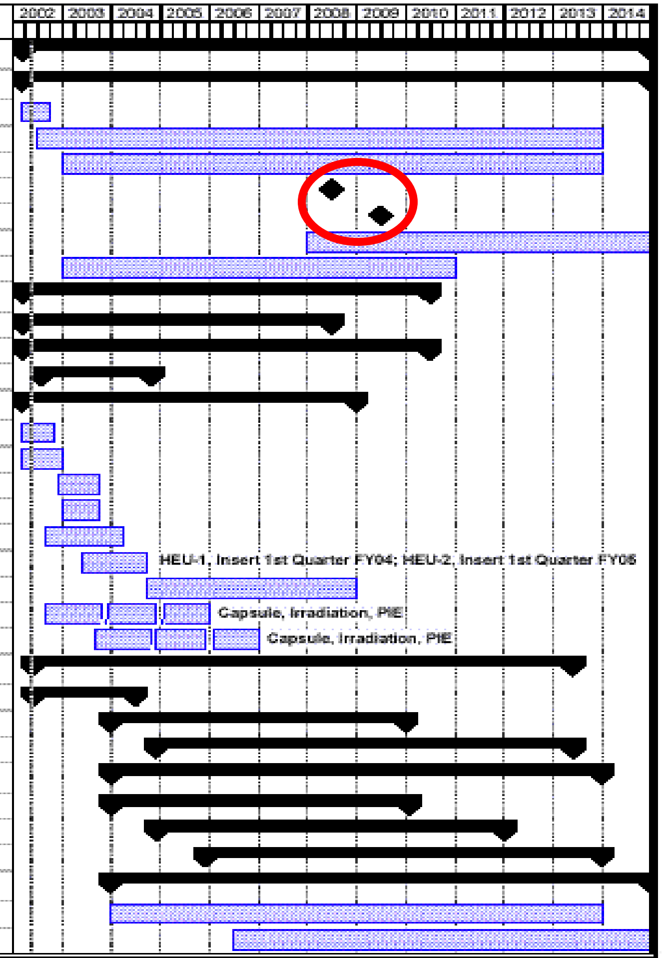
**TRISO Fabrication Facilities**

**Preliminary Fuel Design**

**Fuel Development Plan**

# 5-Year Plan Supports Early Evaluation of TRISO Fuels

| WBS | Task Name |
|---|---|
| **1** | **Fuel Development Schedule** |
| **1.1** | **Fuel Development Planning and Performance Modeling** |
| 1.1.1 | DF/TF Dev. Plan |
| 1.1.2 | DF/TF Performance Modeling |
| 1.1.3 | DF/TF Actinide & Fission Product Transport - Kernels/Coatings/Graphite |
| 1.1.4 | Select Reference DF Design |
| 1.1.5 | Select Reference TF Design |
| 1.1.6 | DF/TF Licensing Database & Proof Test Report |
| 1.1.7 | DF/TF Systems Analysis/Integration |
| **1.2** | **Fuel Design** |
| 1.2.1 | Driver Fuel Design |
| 1.2.2 | Transmutation Fuel Design |
| 1.2.3 | Irradiation Vehicles |
| **1.3** | **Fabrication Technology** |
| 1.3.1 | Establish U-kernel Line |
| 1.3.2 | Design/Install Sintering and Coating Line |
| 1.3.3 | Design/Install Compacting Line |
| 1.3.4 | Install Complete QC |
| 1.3.5 | Depleted Uranium Operations |
| 1.3.6 | Enriched Uranium Operation |
| 1.3.7 | Process Development Support |
| 1.3.8 | HEU-1: HEU Particle |
| 1.3.9 | HEU-2: HEU Compact |
| **1.4** | **Driver Fuel** |
| 1.4.1 | DF Lab Facility for Fuel Fab |
| 1.4.2 | DF Test Fuel Fabrication |
| 1.4.3 | ATW-2 Driver Fuel Irradiation Tests |
| **1.5** | **Transmutation Fuel** |
| 1.5.1 | Remote Fuel Fabrication |
| 1.5.2 | Transmutation Fuel Fabrication |
| 1.5.3 | ATW-2 Transmutation Fuel Irradiation Tests |
| **1.6** | **Accident Testing** |
| 1.6.1 | HEU & DF 1600C Heat Up |
| 1.6.2 | TF 1600C Heat Up |

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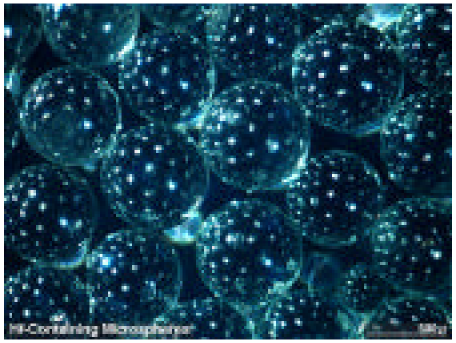
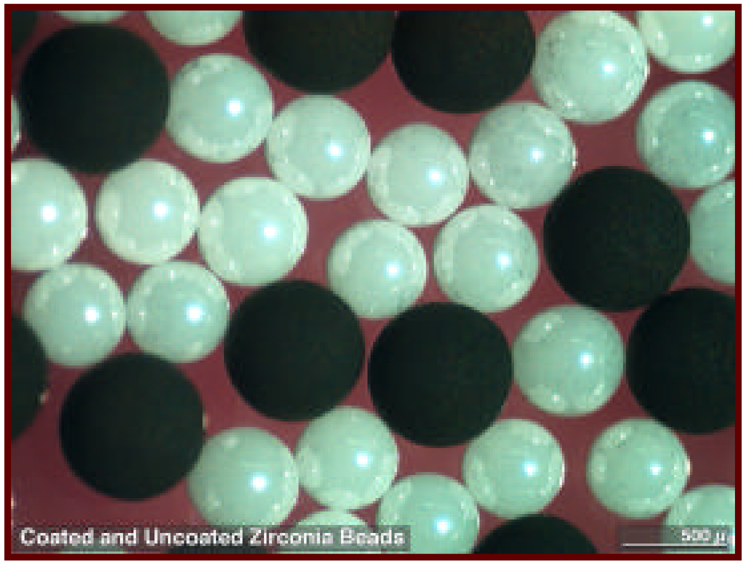
# TRISO Fuels Activity 1.22.04

Surrogate kernels made ($HfO_2$)

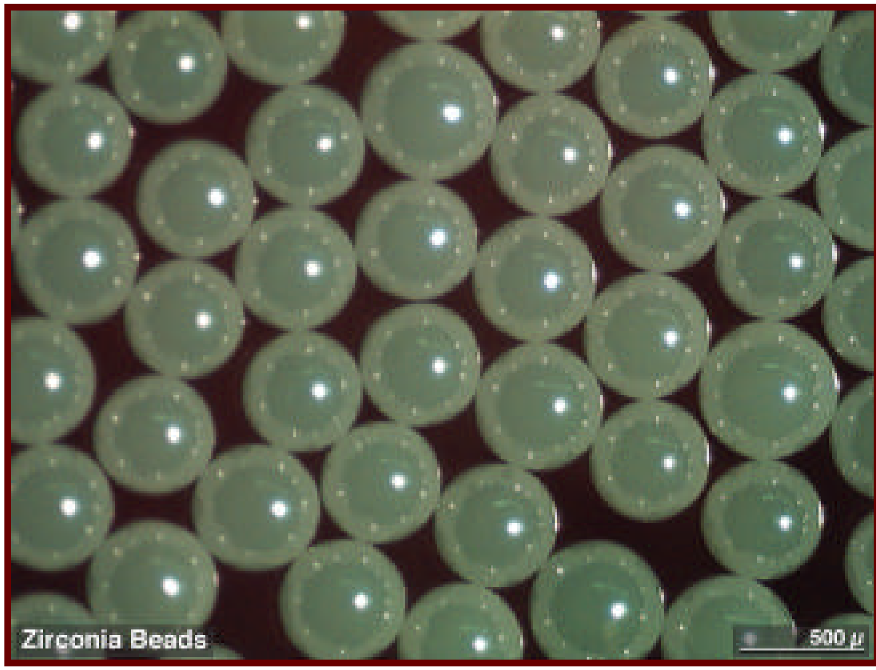



Carbon coating on commercial $ZrO_2$

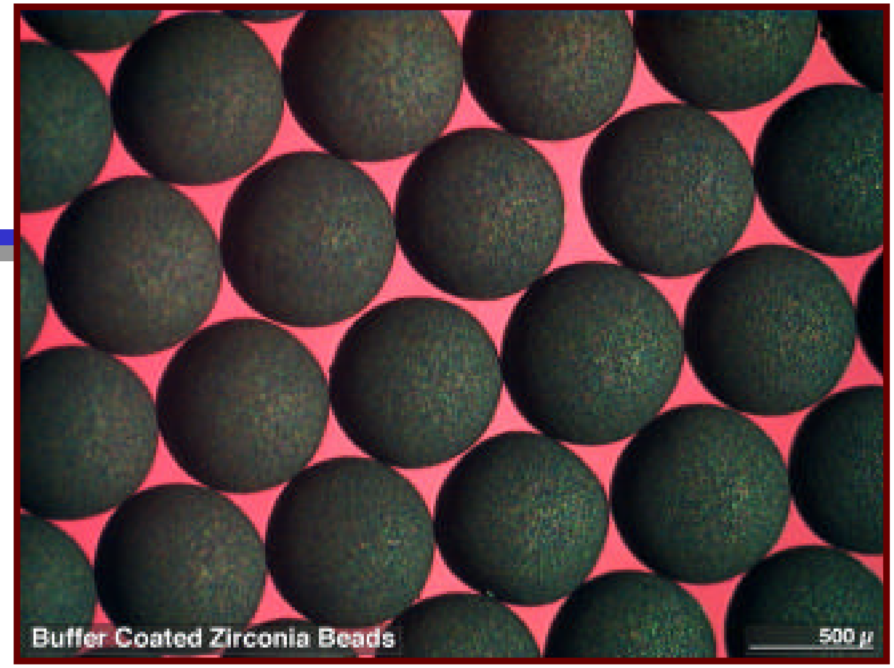



U-Kernels in July

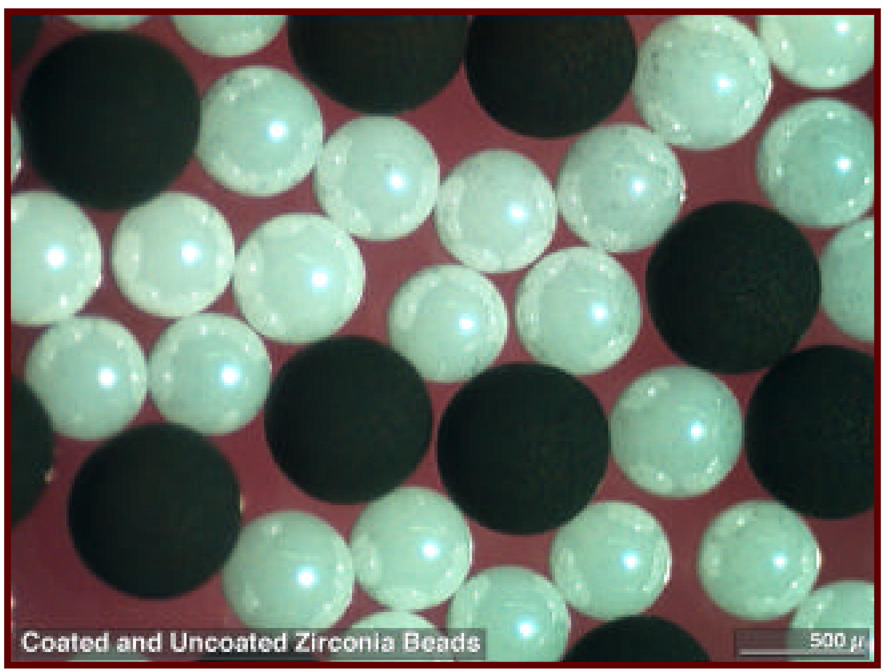
U-coating in August



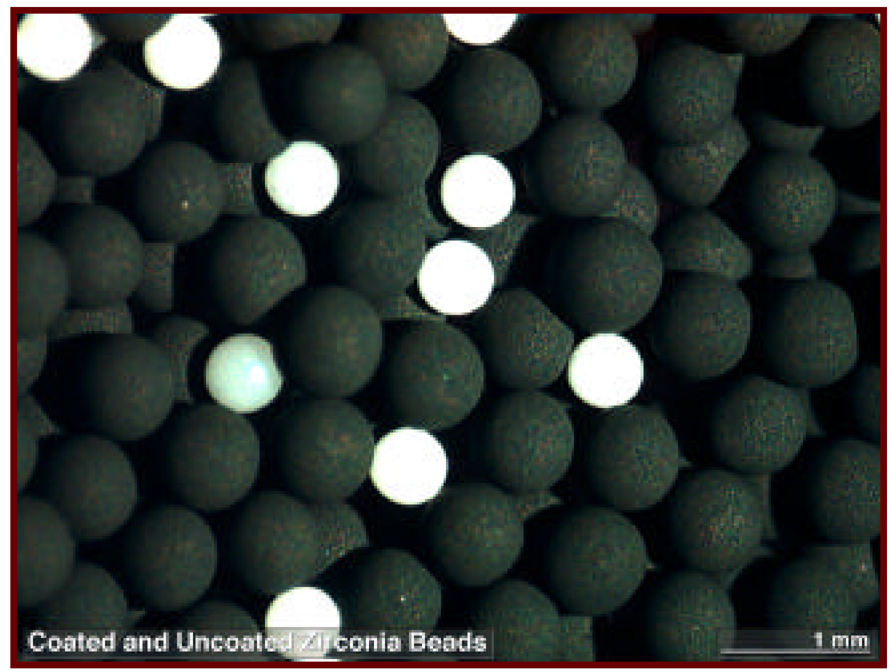
Zirconia Beads



Buffer Coated Zirconia Beads

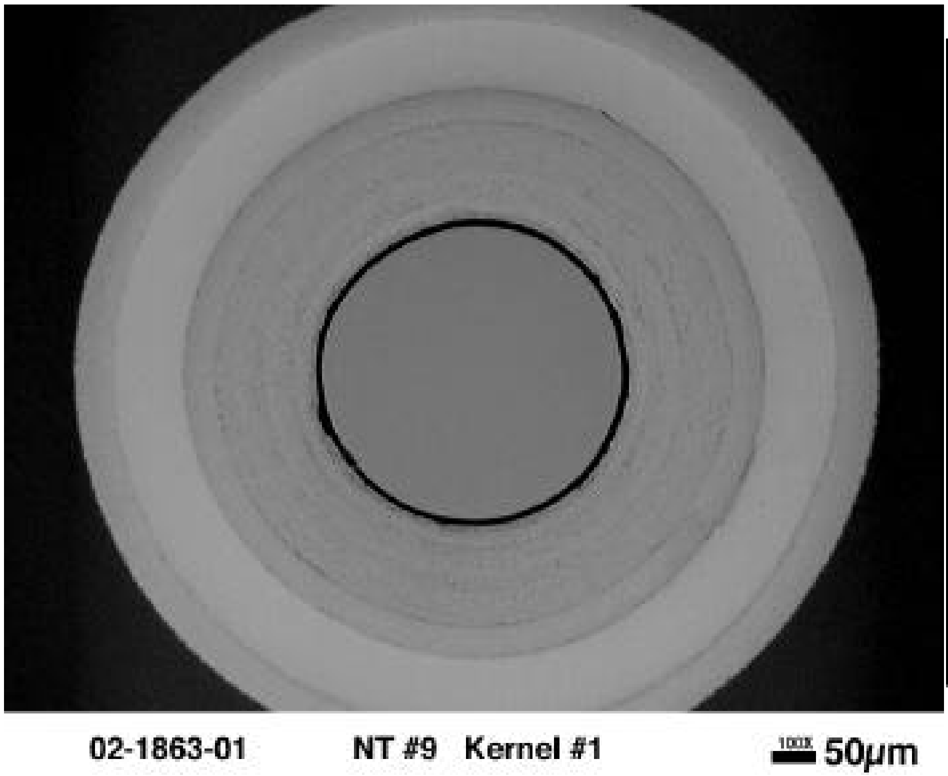


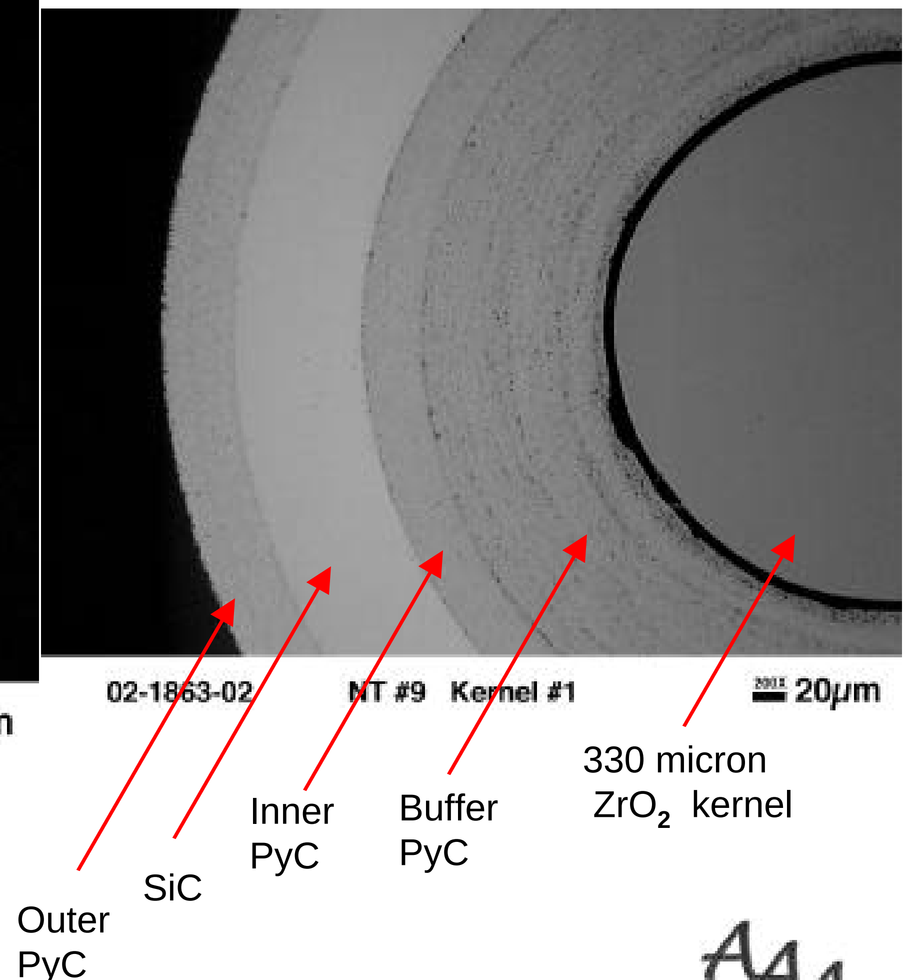
Coated and Uncoated Zirconia Beads



Coated and Uncoated Zirconia Beads

# Surrogate TRISO Fabricated



# *ORNL Dispersion Fuels Activity 1.22.05*

**~100 gm Pu/Am/Np resin-loaded kernels to be made and shipped to ANL for CERMET studies by the end of FY02:**

**50 gm 150 micron diameter**
**50 gm 80 micron diameter**

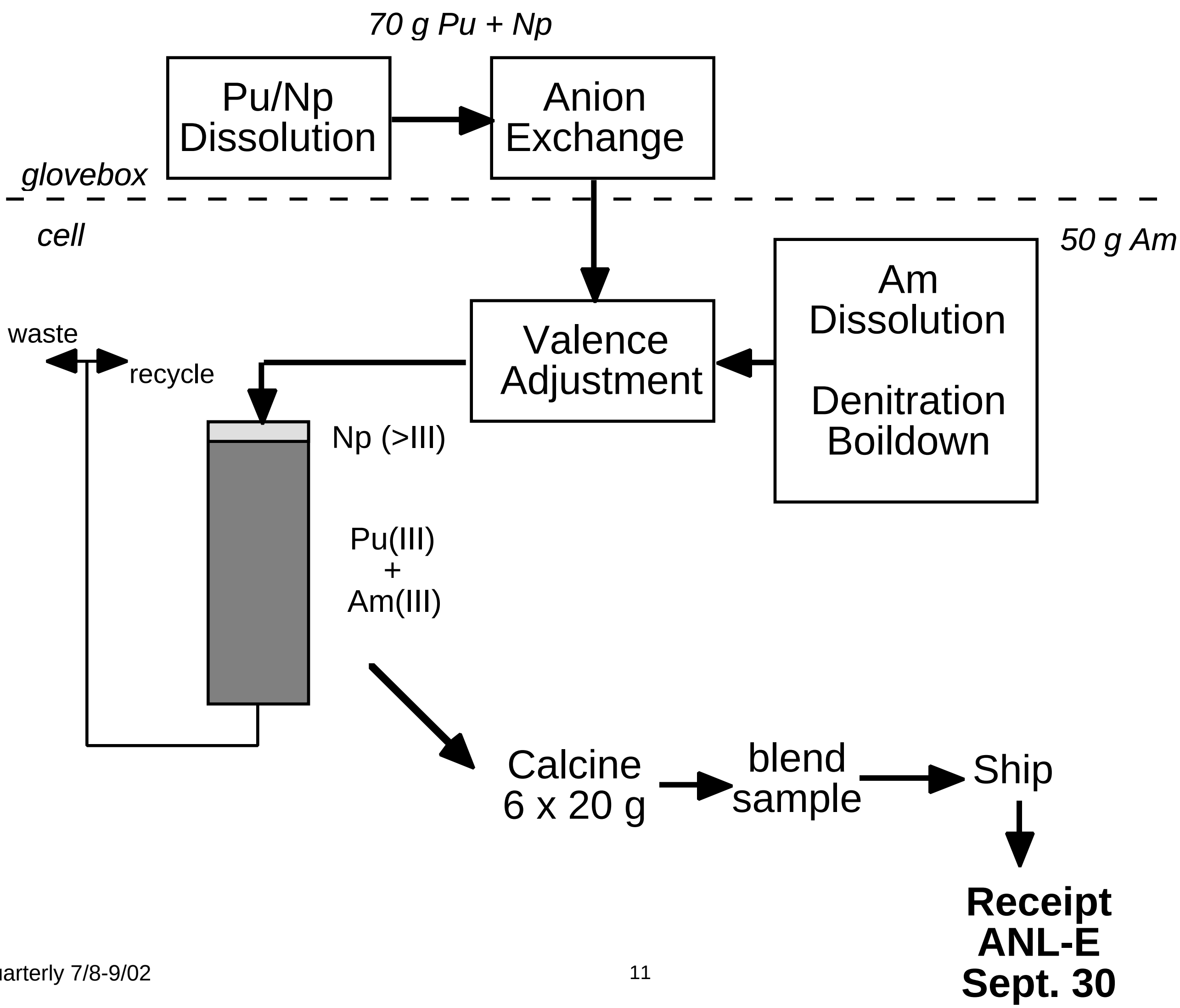
**All Materials on hand**

**Resin-loading process likely to be used for TF**

**Glovebox dissolution of Pu accomplished**

**Hot-cell activities scheduled for July-August**

# Resin-Loading Flowsheet



# Coordination with Reactor Transmutation Activity 1.50.01

**5-yr. Plan Input:**

**keys: micro-scale fabrication**

**potential for shorter time horizon**

**Fuel Development Plan Input Complete - Issue end of July**

**Pu/Np kernels flowsheet complete**

**Preliminary thermochemical analysis of TRISO fuel:**

**Am-volatility manageable**

**Oxygen management more difficult for TF**

**- ZrC getter may be necessary**

# Am Volatility Manageable in Oxide Systems

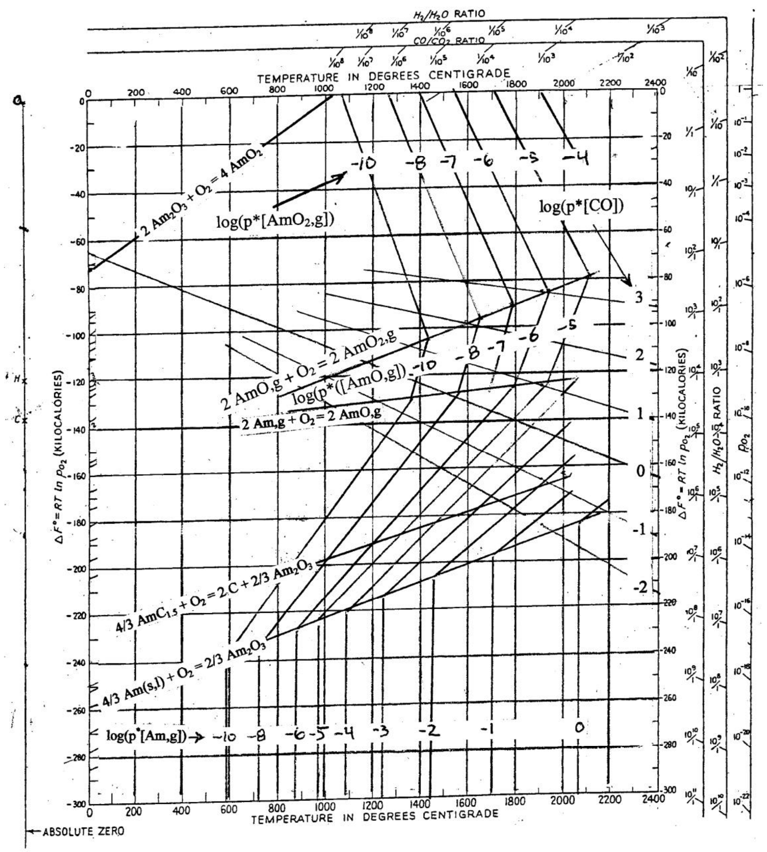



Fig. 1 The Ellingham diagram for the Am-O-C system. The oxygen potentials for the Am,g-AmO,g and AmO,g-$AmO_2$,g equilibria are plotted where the two pressures in each equilibria are equal.

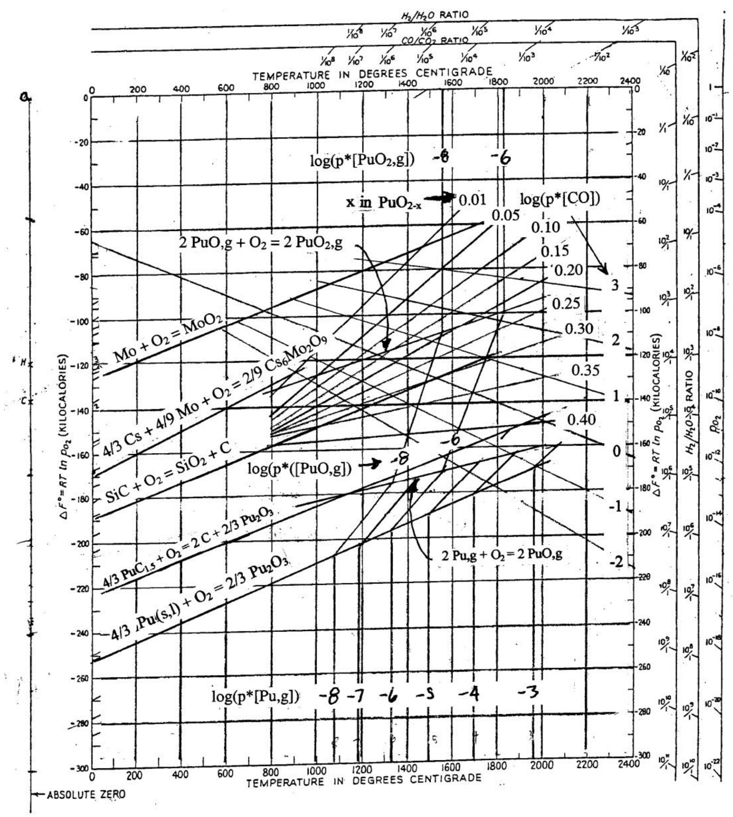


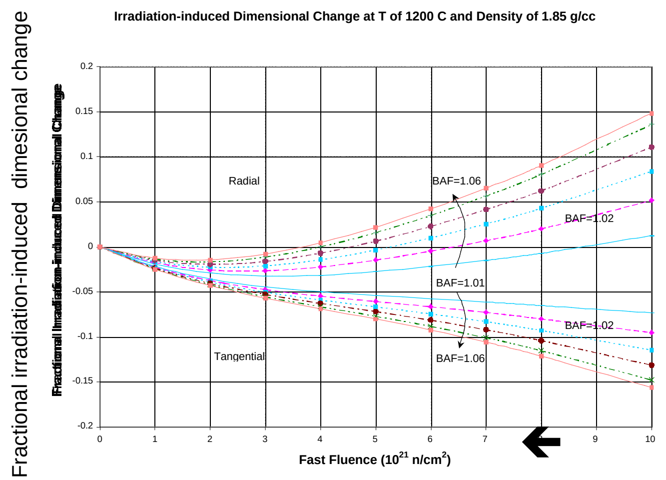

Fig. 2 The Ellingham diagram for the Pu-O-C fuel system. The oxygen potentials for the Pu,g-PuO,g and PuO,g-$PuO_2$,g equilibria are plotted where the two pressures in each equilibria are equal. Several equilibria relevant to the chemistry of fuel performance are also plotted.

Thermochemical Evaluation Report in Preparation

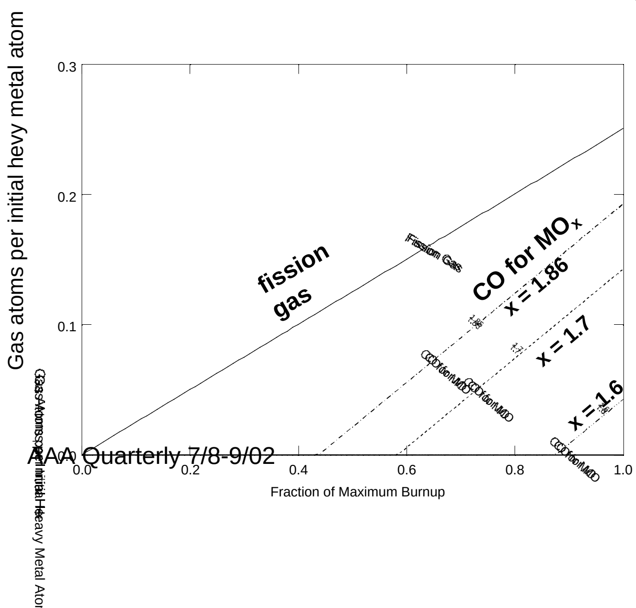


Advanced Accelerator Applications

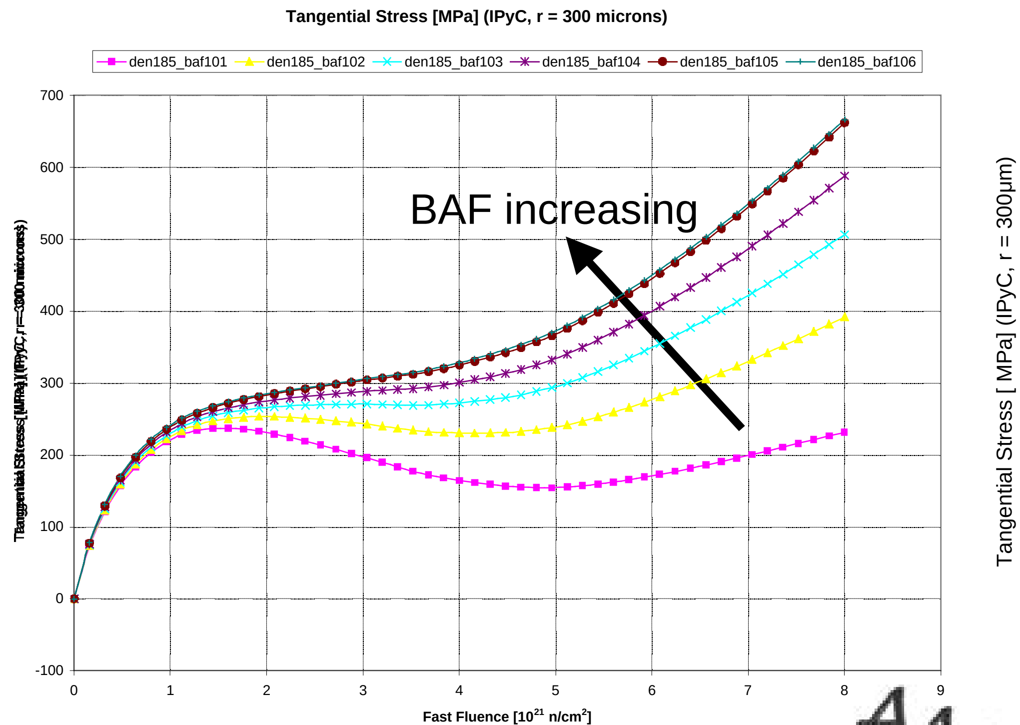
# *Driver Fuel Design Calculations are being used to evaluate particle design alternatives*




## Structural Model Input Dl/l, $a_{co}$




## IPyC Stress is a strong function of PyC Crystallite orientation



# Observations on Particle Design

- **Coating performance strongly dependent on PyC performance**
- **PyC performance is a weak function of internal pressure (BURNUP)**
- **PyC performance is a strong function of fast neutron fluence**
- **PyC performance is a strong function of crystallite orientation and Poisson's ratio for irradiation-induced creep**
- **If either the IPyC or OPyC stays intact, the forces caused by pyrocarbon shrinkage are sufficient to overcome internal pressure forces and keep the SiC in compression (SiC does not fail)**
- **Proven oxygen management techniques can prevent CO formation (e. g., using ZrC as an oxygen getter)**

# *FY02 Activities Status*

**COMPLETE:**

**Non-Radioactive Surrogate TRISO Fabrication**

**Fuel Development Plan (ORNL input)**

**TO COMPLETE:**

**Depleted Uranium TRISO Fabrication**

**Minor Actinide Kernel Fabrication**

**U-TRISO Fabrication Lab**

**Preliminary Fuel Design Review**

# ATW-2: TRISO Irradiation Planning

**6 separate irradiations:**

| | |
|---|---|
| **2 HEU trials to validate DF,TF design and process** | |
| **HEU-1 (unbonded TRISO)** | **Fall 2003** |
| **HEU-2 (compacts)** | **Fall 2004** |
| **2 DF trials: 1 screening, 1 margin test** | |
| **screening (DF1,2 : baseline + alternate)** | **FY05** |
| **margin (DF3)** | **FY07** |
| **2 TF trials: 1 screening and 1 margin test** | |
| **screening (TF1,2: baseline+alternate)** | **FY06** |
| **margin (TF3)** | **FY08** |

**Irradiations can be done in HFIR, ATR, and a number of Foreign Reactors**

# Proposed FY03 TRISO Fuels Activities: Laboratory (1 of 3)

| | |
|---|---|
| **FABRICATION TECHNOLOGY:** | **4 M** |
| · Coating Development | |
| · Kernel Fabrication | |
| · Quality Control | |
| · Sintering | |
| · Irradiation Specimen Fabrication | |
| · HEU-1 Irradiation Capsule | |
| · Compacting Lab | |
| **DRIVER FUEL (DF):** | **6.25 M** |
| · Complete Kernel Line Installation | |
| · Kernel Line Operation (U & Pu/Np) | |
| · Finalize High-Alpha Coater Design | |
| · Install Coating Sector (partial) | |
| **TRANSMUTATION FUEL (TF) + FUEL ANALYSIS** | **0.75 M** |
| · Fabrication Facility Plans for TRISO | |
| · Dispersion Fuel Support | |
| **subtotal-1** | **$11M** |

# Proposed FY03 TRISO Fuel Activities: Design and Analysis (2 of 3)

- **Fuel design, analysis and specifications** **($0.6M)**
  - Structural and chemical design of DF and TF
  - design and specifications for ZrC coatings

    for O2 potential and Palladium attack reduction
- **Fuel systems analyses for transmutation cycles** **($0.5M)**
  - fabrication and handling economic comparisons of Pu Burning only, use of a single particle combining Pu and minor actinides, and the reference two-particle (DF and TF) transmutation cycle
- **Irradiation Test Specifications** **($0.3M)**
  - specifications for test fuel samples
  - specifications for irradiation testing of first

    (U) particles and compacts

# Proposed FY03 TRISO Fuel Activities: Design and Development (3 of 3)

- **Technology Transfer** **($0.6M)**
  - operations support by GA staff assigned to ORNL
- **Compact Equipment Design and Fabrication** **($0.7M)**
  - design and fabricate thermosetting resin compactor system for use in glovebox
- **Remote, automated inspection and quality control equipment design and fabrication** **($1M)**
  - design and fabricate advanced (remote, automated) quality inspection and quality control system

**subtotal-2** **$3.7M**

**TOTAL** **$14.7M**